LITERATURE REVIEW OF BITTERBRUSH
(Purshia Tridentata)

by

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Introduction

Bitterbrush (Purshia tridentata) is a shrub that grows over much of the western mountainous area. It is highly palatable, highly nutritious, and is generally considered to be desirable for a well balanced animal diet.

Unfortunately, animals are not particularly adept at managing their food resources. This ineptness is compounded and encouraged by the greed and selfishness of man. As a result, bitterbrush, "the beef steak of ungulates," has been seriously depleted over much of its natural range. Management to restore this aristocrat of browse requires a sound understanding of the nature, character, and reactions of bitterbrush. Much important literature dealing with this shrub has been compiled and summarized in this report to aid land managers in their evaluation of the bitterbrush resource.

Autecology

Ungrazed Plant Form

Bitterbrush, a member of the rose family, is a semi-erect grayish green shrub. It has an open and abundantly branched form (Handbook, 1937). Flowers are yellow, complete, and are borne solitary on short terminal, leafy spurs on last year's stems (Hormay, 1943a). Leaves are alternate, deciduous, often glandular, and are closely clumped on short lateral shoots. They occur on stems several years old. (See Figure 1)

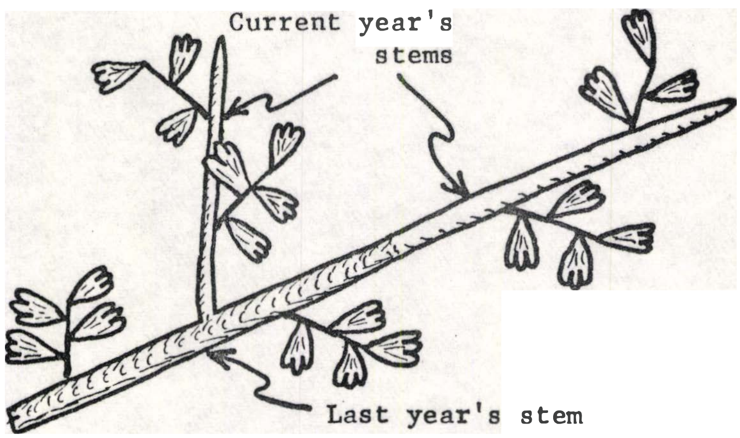

Figure 1. Nature of leaf aggregation

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This clumping arrangement of leaves permits highly selective browsing by animals prior to leaf fall, a point to consider when reading the discussion on sampling use of bitterbrush.

Smith and Urness (1962) found that weight distribution of leaders is not a linear relationship. Figure 2 shows leader taper. Thus, when 50 percent of the twig length is removed, it represents only 40 to 48 percent of the twig weight.

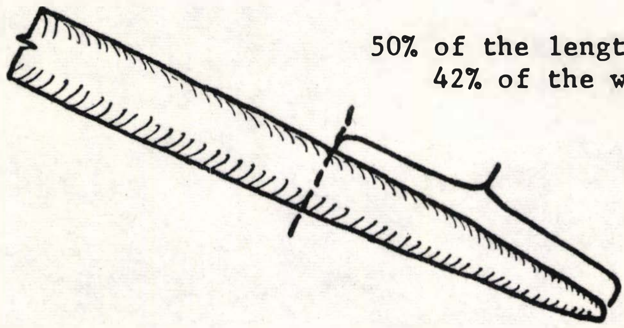


Figure 2. Diagram of Leader taper.

Sanderson (1963), working in northern California, found that leader length varies considerably between plants and between years. He designated "Leaders" as twigs one-half inch or longer to differentiate leaders from flower spurs. However, some leaders often grow less than one-half inch on plants of poor vigor or under poor growing conditions. Both Sanderson, et. al. (1963) and Smith and Urness (1962) question the desirability of the half-inch qualification. Because of leader variability, they concluded that number of leaders per stem and length of the leaders are unreliable measures of vigor. Some difficulty has been found in determining where the current year's twig growth starts due to poor differentiation of bark and bud scars. This apparently becomes more important as the season progresses (Hubbard, 1958b).

Grazed Plant Form

Experimental evidence has demonstrated that deer influence the form of palatable shrubs (Gibbens and Schultz, 1962). They found that continuous but moderate use where terminal buds were nipped prevented excessive height growth of shrubs and kept them within reach of deer. Terminal bud nipping approached 100% well before excessive stem utilization.

The kind of animal browsing bitterbrush will influence the form. Moderate to heavy cattle use causes a mat or smooth form, whereas deer and sheep

use results in numerous, small, isolated clumps of branches which gives the plant a ragged look (Committee, 1951; Hormay, 1964). For management purposes, form classes of bitterbrush have been established which reflect browsing intensity and the availability of plant material. Available browse for deer is that within four feet of the ground. Deer apparently are very selective in their use of current year's growth. Many times they will completely remove the short, leafy spurs (Smith and Urness, 1962).

Hormay (1943a) noticed that grazed bitterbrush tends to stay green longer in the fall.

Root System

Bitterbrush has a semi-taproot system which separates into two or three major secondary roots at the one- to two-foot depth. Numerous small secondary roots branch from the major taproot and form a meandering, rather simple, fiberous system with strong vertical growth and moderate lateral spread. Adventitious branching along the main and secondary roots tends to be restricted to finer textured soil strata.

Overall rooting depth varies considerably. In deep soils it may extend 15 to 18 feet (McConnell, 1961). Hormay (1943a) found that bitterbrush roots penetrate 15 to 20 inches in northern California during the first year's growth. Stanton (1959) found that taproots would grow 3 to 3-1/2 feet during the first year in coarse textured soils. See Appendix 1 for bitterbrush root diagram.

Seasonal Development

Bitterbrush bursts leaf buds early in the spring and flower buds begin to enlarge and burst a few weeks later. Flowers are well developed prior to significant twig elongation and correspond to the time of general leaf development on older shoots. Active stem elongation starts after flowering (Hyder and Sneva, 1962; Sneva, 1963). Twig growth continues during most of the summer and into September under favorable growing conditions (Hormay, 1943a). Fruits develop and ripen about the middle of summer. Leaves are shed in October and November (Hormay, 1943a).

Seeds are contained within a fleshy coating which turns red and exudes a red juice about the time seeds are ripe. After ripening on the plant, seeds generally fall to the ground within one week. On the ground, the seed coat dries, hardens, and cracks (Holmgren and Basile, 1959; Committee, 1963). Seed development and ripening depend upon local climatic condition. In southern Idaho, seed is often ripe during the first week in July at 3,000 feet while at 5,000 feet it ripens four weeks later (Holmgren and Basile, 1959). Stanton (1959), working in Oregon, found seed ripe in mid June at 300 feet elevation while it is five to six weeks later at 5,000 feet.

In California, seeds germinate and seedlings emerge in the spring at about the same time parent plants start to grow. Young plants seldom grow more than two or three inches tall the first season. Flowering of ungrazed plants starts in the fourth to fifth year on good sites and in the sixth to eighth year on poor sites. At this time plants are 8 to 10 inches tall. Browsed plants take longer to start flowering. Seed production usually becomes important at 10 years of age or later (Hormay, 1943a).

Plants produce one growth ring per year and probably live from 60 to 70 years (Hormay, 1943a). Basal stem diameter is related to age of bitterbrush; however, it varies between sites, and between intensities of use (McConnell and Smith, 1963).

Nutritional Value

Most of the nutrients in bitterbrush are contained in the leaves and buds. Shorter stems contain greater amounts of protein, fat, ash, and carbohydrates and less crude fiber. During the winter, tip or bud ends of the stems have higher nutrients. Nutrient content declines in the fall with the loss of leaves (Aldous, 1945).

Seasonal and yearly differences in nutrient status have been found statistically significant by Dietz, et. al (1962b). Figure 3 shows seasonal changes in protein and fiber. During the summer, bitterbrush is higher in protein, ash, calcium, and phosphorous, with less fiber than during the winter (Hagen, 1953; Dietz, et. al. 1962b). Hagen (1953) found that on heavily grazed winter range the available nutrient content of bitterbrush changed even more drastically because nutritious terminal buds were consumed first, leaving lower quality stems for the critical late winter feeding.

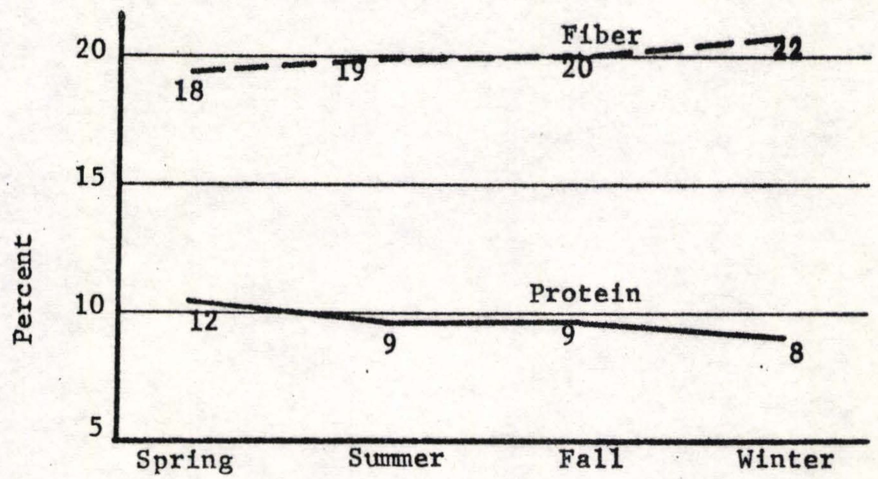


Figure 3. Seasonal change in protein and fiber.

Dietz, et. al. (1962b) found significant differences in nutrient content between locations at the same time of year. Figure 4 illustrates various levels of protein in bitterbrush during the winter over widely separated geographic areas (Bissell and Strong, 1955 - California; Smith, 1957 - Utah; Dietz, et. al. 1958 - Colorado).

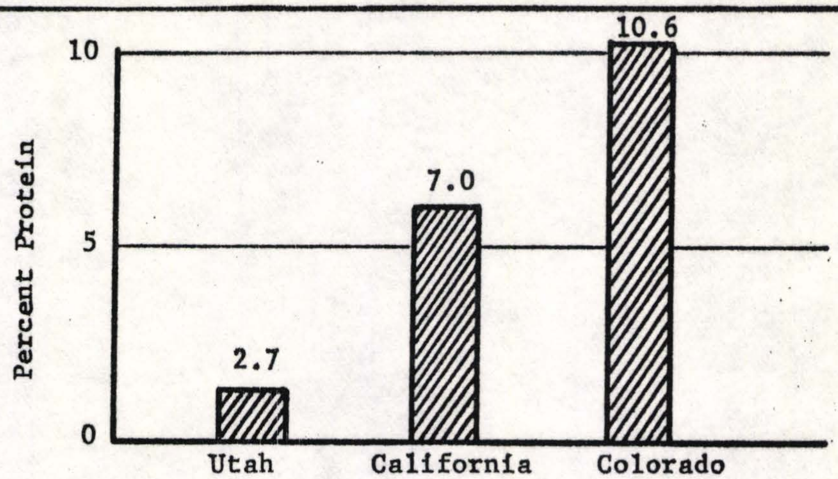


Figure 4. Winter protein content of bitterbrush.

Nutrient content of bitterbrush differs from other browse species. In all cases it was found to be lower than sagebrush (Artemesia tridentata) and mountain mahogany (Cercocarpus ledifolius). Sage was much higher in nutritive value during middle and late winter, mainly because the highly nutritious leaves are retained (Dietz, et. al. 1962a; Yeager, 1960; Hagen, 1953; Smith, 1957).

The winter nutritional value of bitterbrush has generally been found satisfactory. Only Smith (1957) in Utah found protein to be lower than the five percent minimum required for wintering animals. In general, bitterbrush contains about 7 percent protein, 17 percent phosphorous, a calcium-phosphorous ratio of about 6 to 1 (2 to 1 is most desirable), and 22 percent crude fiber. This is satisfactory but not outstanding nutritive balance (Bissel and Strong, 1955; Dietz, et. al. 1958; Yeager, 1960).

Pen feeding trials have demonstrated that deer will gain weight on a pure diet of bitterbrush. A mixture of browse resulted in reduced digestibility of individual species. However, animals on a mixture of browse gained weight better than those on a single species diet, demonstrating the desirability of a forage mixture. (Dietz, et. al. 1962a and b).

Reproduction

In California, Oregon, and Washington, bitterbrush reproduces mainly from seed buried in caches by rodents. Chipmunks and goldenmantle squirrels are most important. The seed is generally found buried one-quarter to one and one-half inches deep. Natural dissemination of seed is largely a result of these rodents. Seedlings survive best in openings between shrubs. Re-establishment of bitterbrush after fire depends, to a large extent, on the nature of the vegetation. Rodents hesitate to cache seeds in soft chess (Bromus mollis) and cheatgrass (Bromus tectorum) types (Hormay, 1943a; Nord, 1959a; Stanton, 1959).

Viable seeds generally have a smooth coat that varies in color from light bluish gray to purple gray and dull pink. Seeds with a black, minutely rough surface are not viable. These non-viable seeds often persist on the shrub after the sound seeds have dropped. Seeds without husks apparently produce seedlings with better survival. Bitterbrush seed requires over-wintering to break dormancy. Germination remains high for three to five years.

The time of germination and the following two or three weeks are the most critical periods for seedling establishment. Soil moisture must be constantly available. Soils of high clay content tend to crust and prevent seedling emergence. Frost heaving commonly damages germinating seedlings in the late winter and early spring. Temperatures that fluctuate between 50 degrees F and 90 degrees F are more favorable than constant temperatures (Holmgren and Basile, 1959; Stanton, 1959).

Bitterbrush will reproduce vegetatively by means of stem layering, adventitious buds, and meristematic tissue at the soil surface. Vegetative reproduction is generally limited to areas east of Oregon and California (Blaisdell and Mueggler, 1956b). Stem layering occurs in California from adventitious buds where the stems touch the ground or are covered with soil. This may occur in 20% of the plants in certain communities. Sprouting from adventitious buds at the root crown occurs infrequently in California and Oregon (Hormay, 1943a; Nord, 1959b; Driscoll, 1963; Stanton, 1959). In the eastern range of bitterbrush, sprouts originate in two ways: from a ring of dormant buds at the root collar, and from a mass of meristematic tissue at the ground level. Between 50 and 75 percent of the plants will sprout by one of these two means. Date of top removal (burning or rotobeating) has little effect on sprouting. However, an intense fire will reduce sprouting when sufficient heat is present to kill buds and meristematic tissue (Blaisdell and Mueggler, 1956).

Animals greatly influence the reproductivity of bitterbrush particularly in those areas where it reproduces by seed. Flowers, and the seeds, are borne on the second year's growth of terminal leaders. Any browsing use

of terminal leaders will, therefore, reduce the flower and seed producing capacity for the following year. If 50 percent of the leader length is removed, flower and seed producing ability will be reduced about 50 percent the next year. Satisfactory seed production can be maintained only by limiting the amount of leader growth removed. Recommendations vary from 40 to 65 percent depending on site and growing conditions (Hormay, 1943a; Holmgren and Basile, 1959). Different animals influence the reproduction of bitterbrush in different ways. Yeager (1960) demonstrated that cattle caused the least damage to reproduction, sheep the greatest damage, and deer were intermediate in their effect.

Bitterbrush may not always reproduce in areas on which it is growing (Committee, 1963). Lack of reproduction in the Devil's Garden area in Modoc County, California, was largely due to bitterbrush's successional status in the vegetation. At one time, the area was grassland with occasional Ponderosa pine. Heavy overgrazing at the turn of the century reduced grass competition and apparently permitted reproduction and increase of bitterbrush. With the present non-use by livestock, grass competition is becoming severe and is not only preventing bitterbrush reproduction but also reducing vigor.

Genetics

Bitterbrush has many genetic strains and yet some genetic plasticity (Plumber and Jensen, 1956; Committee, 1963; Nord, 1959; Blaisdell and Mueggler, 1956). Nord (1959) has found that *Purshia tridentata* will hybridize with *Purshia glandulosa* and *Cowania stansburnii*. Stanton (1959) found differences in germination and cold resistance between central Oregon and northern California strains. Seed source has been shown to influence survival of seeded stands (Plummer and Jensen, 1956). Unless proven otherwise, one should assume that a particular strain of bitterbrush is associated with each vegetation type in which it occurs (Nord, 1962).

Physiology

Seasonal development of bitterbrush is related to its susceptibility to use. Apparently winter use is least detrimental. This resistance to use is maintained through spring development until flower buds begin to swell. Resistance then decreases and remains moderately low during flowering and active twig elongation.

After leaf fall, resistance to grazing again increases (Hyder and Sneva, 1962; Sneva, 1963). Garrison (1953) demonstrated bitterbrush resistance to use during the winter. After seven years of clipping all of the current leader growth, the plants were in poor vigor but had not died. He suggests that 60 to 65 percent of the twig length removal on good sites and 50 percent on poor sites will not be detrimental to bitterbrush. Apparently clipping stimulates twig production to the detriment of flower and fruit production. Hormay (1943a) concurs in this amount of use. This high tolerance to winter use probably explains why bitterbrush plants have persisted in areas of heavy and extreme use.

Growth form of bitterbrush affects its resistance to grazing. Hormay (1964) found that the smooth, compact form caused by cattle can result in total grazing tolerance even though all the available leader growth is removed. The dense, stiff branches prevent removal of all leader growth and little removal of leaves on older wood. Under these conditions, bitterbrush remains in better vigor than ungrazed plants and will produce maximum seed and leader length during years of non-use. On the other hand, the open, ragged form caused by sheep and deer browsing results in all current leaders and leaves on older stems being available. In this case, vigor can easily be reduced with "moderate" or heavy use.

Enemies

Bitterbrush suffers at the hands of many agents such as rodents, insects, disease, fire, and weather. Field mice, squirrels and chipmunks damage seedlings by feeding on the cotyledons or severing the young plants at the ground (Plummer, 1958; Hubbard, et. al. 1959; Holmgren and Basile, 1959; Nord 1959a; Stanton, 1959). Bitterbrush seed is an important food to many rodents. Rabbits are variable in their effect on bitterbrush. In Idaho, jackrabbits may be particularly destructive to germinating plants during periods of high rabbit populations (Plummer, 1958; Holmgren and Basile, 1959). In California, McKeever and Hubbard (1960) found that jackrabbits, during a high population period, browsed two-thirds of the available bitterbrush plants but did little damage. The rabbits preferred winter fat (Atriplex canessens) and shadscale (Grayia spinosa) and would cause a reduction in these species if the high population persisted. Pocket gophers occasionally damage bitterbrush but their use seems to be incidental (Plummer, 1958; Holmgren and Basile, 1959).

Tent caterpillars have caused widespread damage to bitterbrush through defoliation (Committee, 1951; Hubbard, et. al. 1959; Holmgren and Basile, 1959). Seedlings have been damaged or killed by cut worms which eat the cotyledons or entire seedlings, and by wire worms which eat root systems prior to hardening. Mortality due to these insects may be as high as 90 percent (Hubbard, 1956b; Hubbard et. al 1959; Holmgren and Basile, 1959). Bud worms and leaf rollers are sometimes common but inhibit rather than prevent seedling development (Holmgren and Basile, 1959). Damping off of seedlings is probably the most serious and widespread disease of bitterbrush (Holmgren and Basile, 1959).

Fire has been found universally detrimental to non-sprouting bitterbrush (Countryman and Corneliuss, 1957; Committee, 1951; Hubbard, et. al. 1959; Weaver, 1957).

Frost heaving has often damaged germinating seedlings and may persist in its effect into the second year (Hubbard, et. al. 1959; Holmgren and Basile, 1959; Stanton, 1959).

Synecology

Range of the Species

Bitterbrush grows from the edge of the great plains in New Mexico north to Montana and west to California and British Columbia. It occurs in arid plains and foothills, on mountain slopes, and in forests. It occurs from near sea level in Oregon to 9,000 feet in New Mexico. Any species with such a wide distribution will occur in many different kinds of vegetation.

Rocky Mountain Communities

In Colorado, bitterbrush occurs at 7,900 feet as a major component of a shrub community with mountain mahogany (*Cercocarpus ledifolius*), big sagebrush (*Artemesia tridentata*) and grass on south slopes. On north slopes at the same elevation, it grows with Douglas fir (*Pseudotsuga menziesii*) Juniper (*Juniperus occidentalis*), sage, ninebark (*Physocarpus malvaceus*), and grass. At 8,000 feet it becomes a minor component of the shrub vegetation which is dominated by serviceberry (*Amalanchier alnifolia*), mountain mahogany, big sage and oak (*Quercus* species), (Yeager, 1960).

McConnell and Dalke (1960) found several bitterbrush communities in southern Idaho. At times it forms extensive pure stands with an understory of bunchgrass, at other times it is mixed with big sage. As elevation increases, snowberry (*Symphoricarpos albus*), ceanothus (*Ceanothus velutinus*), cherry (*Prunus* species), and currant (*Ribes* species) increase in importance and bitterbrush decreases. Daubenmire (1952), working in Northern Idaho, found bitterbrush to be an important member of a forest community composed of Ponderosa Pine (*Pinus Ponderosa*), bluebunch wheatgrass (*Agropyron spicatum*), and Idaho fescue (*Festuca idahoensis*).

Oregon and Washington Communities

Bitterbrush ranges from a dominant to a minor component of the plant community. It appears in both forest and non-forest types.

In Washington, bitterbrush dominates a shrub type with Kentucky bluegrass (*Poa pratensis*), serviceberry, snowberry and cherry at middle and upper elevations (Everson and Clark, 1946). In the Blue Mountains, it is important in a big sage-Idaho fescue type within the forest zone (Sneva, 1963). It may also occur as a very minor component of the low sage-wheatgrass type on shallow soil (R-6 C&T Standards). In southern Oregon, it occurs as a minor component in a juniper type with big sage, bluebunch wheatgrass and Idaho fescue (Committee, 1951).

The occurrence of bitterbrush in forest vegetation is equally diverse. In southern Oregon it may occur as a major component under lodgepole (*Pinus contorta latifolia*) or Ponderosa pine accompanied by a sparse stand of stipa (*Stipa* species), Ross' sedge (*Carex rossii*) and squirrel tail (*Sitanion hystrix*) (Dyrness, 1960; Volland, 1963; Youngburg and Dyrness, 1959; Stanton, 1959). It may also dominate the subordinate vegetation in open stands of Ponderosa pine bordering non-forest vegetation. Bitterbrush is also important in the pine-fescue-stipa type (Sanderson, et. al. 1963; Committee, 1951). It occurs as a minor component in the forest vegetation at upper elevations with ceanothus and manzanita (*Arctostaphylos patula*).

In the Blue Mountains it appears in the pine-elk sedge (Carex geyeri) type and is a dominant in the pine-bitterbrush-Ross' sedge type (R-6 C&T Standards). In Washington it occurs on the south slopes in open Ponderosa pine with bluebunch wheatgrass, balsam root (Balsamorhiza sagittata) and cheatgrass (McConnell, 1961).

Soil

The soils on which bitterbrush grows may be derived from granite, sedimentary, sandstone, shale, basalt, andesite, rhyolite, serpentine, and pumice. The soils may be derived in place, wind or water deposited, or colluvial (Holmgren, 1954; Nord, 1959; McConnell, 1961; Youngburg and Dyrness, 1959; Volland, 1963; Dryness, 1960; R-6 C&T Standards).

Best development of bitterbrush is on soils that are excessively drained, coarse textured and slightly acid (pH 6.0 to 7.0 extending to a depth of 5 feet). Generally the soils are only moderately fertile. Bitterbrush development is poorer on saline or calcareous soils, or on soils with fine texture. Coarse textured soils range from pea sized pumice and granite to sandy loams. Soil depth may vary from 15 to 20 feet of pumice or glacial drift to 10 to 12 inches of soil over a well broken bedrock (Holmgren, 1954; Hubbard, et. al. 1959; Daubenmire, 1952; Hormay 1943a; Nord, 1959; McConnell, 1961; Youngburg and Dyrness, 1959; Volland, 1963; Dyrness, 1960; R-6 C&T Standards).

Certain soil characteristics influence the presence of bitterbrush. High water table results in poor vigor. Bitterbrush will not grow on soils that are seasonally flooded (Youngburg and Dyrness, 1959). Fine textured soils that grow vigorous perennial grasses are associated with reduced bitterbrush vigor (Volland, 1963; Dyrness, 1960; R-6 C&T Standards).

Climate

Each plant species has its own rate of growth and development which is influenced by temperature and precipitation. This rate varies between types of vegetation during the same year and within the same type of vegetation between years. The time of year when a plant reaches a certain developmental stage is thus influenced by elevation. In Colorado, plant development is delayed 10 to 14 days for each 1,000 feet increase in elevation. However, once started, growth is more rapid at higher elevations. The variations in plant development and growth tend to be greater at lower elevations. In some cases, initiation of spring growth may vary by as much as 45 days (Costello and Price, 1939).

Blaisdell (1958), working in eastern Idaho, found highly variable differences in bitterbrush production between years as a result of variations in the amount of precipitation. Time and rate of growth varies considerably from year to year and is largely dependent upon temperature.

Bitterbrush occurs within a wide range of precipitation. The minimum is 9 to 10 inches in California and the maximum is 23 to 34 inches in eastern Oregon and Washington (Garrison, 1953; Holmgren, 1954; Nord, 1959a; Holmgren and Basile, 1959; Sneva, 1963; Volland, 1963; Dyrness, 1960; Stanton, 1959).

Yeager (1960) has associated the presence and vigor of bitterbrush with temperature relationships in Colorado. It tends to be more important on south slopes with higher winter temperatures. However, it increases in importance with increasing elevation corresponding to a two degree decrease in temperature per 1,000 feet. The temperature-bitterbrush relationship appeared to be related to cooler summer temperatures and warmer winter temperatures. Youngburg and Dyrness (1959) found it growing vigorously in frost pockets within the Ponderosa pine zone in southern Oregon. The microclimate in this case favored lodgepole pine to the exclusion of Ponderosa pine. Bitterbrush can also withstand periodic freezing during the growing season (Stanton, 1959).

Elevation and the importance of bitterbrush are directly related. Volland (1963) and Dyrness (1960) found it to be of greatest importance in the forest community at lower elevations. It decreased and was gradually replaced by other shrubs as elevation increased. Yeager (1960), on the other hand, found an opposite reaction with bitterbrush in Colorado. There it increased in importance with increasing elevation to 8,000 feet.

Competition

Bitterbrush must compete with itself, herbaceous vegetation and trees. Hubbard, et. al. (1962), working in northern California, found that ten feet between seven year old bitterbrush plants results in minimum competition; three feet spacing results in severe competition. A five-foot average spacing represents about 2,200 plants per acre which is the maximum stocking recommended on a good site. Under stocking is desirable to over stocking because it results in more vigorous plants which will grow faster and produce forage more quickly. Natural bitterbrush stocking on good sites is 780 to 1,400 plants per acre.

Most competition with bitterbrush is caused by herbaceous vegetation. Cheatgrass is a maximum competitor with bitterbrush seedlings--a good stand of cheatgrass will completely eliminate the seedlings (Holmgren, 1956). Broadleafed summer annuals compete less than cheatgrass but still cause mortality and low vigor of the seedlings. In spite of this, bitterbrush has been found to have strong competitive ability compared to other browse species (Holmgren and Basile, 1959). Sanderson, et. al. (1963) and Hubbard, et. al. (1962) have reported that perennial bunchgrasses such as squirreltail, fescue and stipa can compete so severely with bitterbrush as to apparently prevent reproduction, reduce vigor, and reduce forage production. Hubbard et. al. (1962), showed that crested wheatgrass (*Agropyron desertorum*)

severely competed when less than two feet from bitterbrush. Mueggler (1950) found that deterioration of forbs and grasses caused by overgrazing decreased competition with bitterbrush and permitted shrubs to increase in the composition. Hormay (1943) has reported that bitterbrush grows better in forest openings than within the forest.

Evaluation of competition in regard to bitterbrush may not always be a simple matter. Sanderson, et. al. (1963) evaluated the effect of perennial bunchgrass competition on bitterbrush in northern California. They completely eliminated the herbaceous vegetation in one area and left it in another. Two years after this weeding, the bitterbrush in the weeded area was only slightly more vigorous than that in the unweeded. This suggests that poor bitterbrush vigor was caused only in part by the bunchgrass competition. Apparently this was a poor site for bitterbrush.

Hormay (1964) found that bitterbrush may be maintained in areas where it is seral by means of cattle grazing. An exclosure study showed that protected plants became decadent, generally failed to reproduce, and even died after twenty years, while the cattle grazed area still contained abundant bitterbrush which was reproducing. He felt that the vigor was maintained at a high level under rest-rotation grazing by cattle.

Management

Big game is one of several wildland products. Abundance and quality of the game crop is determined largely by the effects of agriculture, forestry, and range management. These can be both beneficial and detrimental. Great opportunities for improving wildlife habitat lie in the modification of these practices. Game habitat management must be integrated with the management of all the other resources. We know something about management of these other resources, but little regarding their coordination with game management. To evaluate this problem, we must know something about sampling, production, palatability, and condition and trend of game range as well as management of the animals.

Sampling Methods

Measurement of bitterbrush utilization has been given considerable thought and study. Direct estimation of use is accomplished by classifying each plant in a broad use category such as light, moderate, and heavy. This may be aided by comparing caged and uncaged plants. A refinement is to estimate the percent of the number of twigs that were grazed. This must be related to a more precise method for determining use. Ocular estimate methods have the advantage of speed and the disadvantages of large observer error and requiring considerable observer training (Symposium, 1962).

Hormay (1963) combined estimation and measurement for determining use on bitterbrush. He measures the average diameter of each plant and then estimates the average length of ungrazed twigs and the percentage of the total twig growth grazed. With these values, he calculates an index of forage production and percent utilization. See Appendix II for details.

Measurement techniques can be accurate but require a great deal of time (Symposium, 1958). Smith and Urness (1962) found that 100 to 250 tagged branches are required to satisfactorily sample bitterbrush at 50% use. Heavier use requires fewer branches and light use requires many more. One branch per bush is tagged and the length of all twigs over one-half inch is recorded in the fall prior to game use. The same tagged branches are measured again in the spring. (See also Appendix III). The difference in total length is expressed as percent of use. Extreme care is required for measuring all twigs. Even under very light use, only 23 percent of the branches had the same number of leaders in the spring as they had in the fall. This may mean that some twigs were overlooked or that some short ones were browsed back to the main stem even under light use (See Appendix III for details).

The tagged leader method is similar (Symposium, 1962). Here each leader is labeled and its length measured before and after use. The difference in individual leader length when related to the twig form factor, is a measurement of percent use. These percents are averaged for each bush and again for all bushes.

The most laborious method is before and after clipping. Bushes are randomly selected. All available current year's growth is clipped prior to grazing. After grazing, a number of different bushes are again clipped. The difference in weight represents the amount of forage taken and the percent used. Except in rare cases, this method is too time consuming to be practical (Symposium, 1958).

For any utilization method, one must establish criteria for defining "Available twigs." Results will be biased unless all measured twigs are equally available for use.

Evaluation of livestock and game competition requires a variety of methods. Where these animals frequent the range at different seasons, a before and after method of sampling is simplest (Julander, 1958). Real problems occur when livestock and game are present at the same time, such as on summer range. Julander (1958) evaluated this problem using a variety of methods. He measured pellet group counts of deer and livestock, recorded indicators of use such as highlining, hedging, and animal tracks, and mapped areas grazed intensively by deer and intensively by livestock. He also recorded use on plants that were palatable only to domestic livestock and those only palatable to game animals. His evaluation of competition was based on all these factors and of necessity was dependent upon observer skill.

The composition of bitterbrush in relation to other vegetation can be determined by any of the standard methods such as line intercept, three-step, and crown cover plots (Symposium, 1962).

Forage production of bitterbrush may be determined by indices (Hormay, 1943b), or clipping (Symposium, 1958). Direct methods of determining production are extremely laborious and time consuming. Since game numbers are seldom known and their control is limited, accurate determination of bitterbrush production seems of limited value.

Production

Bitterbrush production fluctuates a great deal between years. In Oregon, Garrison (1953a) found yield varied 300 percent from one year to another. This was influenced mainly by the September through October precipitation. In eastern Idaho, production was correlated with spring precipitation and temperature (Blaisdell, 1958). Schneider (1963) found a one year lag in increase of bitterbrush production in Oregon following a season of high precipitation, but production goes down immediately during a year of low precipitation. He also found considerable variation in production over the state during any one year demonstrating that the general climate cannot be a sound indicator of the general growth of bitterbrush. Plant competition, as noted previously, will greatly influence production. Hubbard, et. al. (1960) found that in northern California there is no direct relationship between weight of leaders produced and size or age of plant. The largest plant produced about the same amount as the smallest even though one was four times larger than the other.

Utilization of bitterbrush apparently affects production. When canopy portions were chopped off three feet above the ground, there was a three-fold increase in production (Basile and Ferguson, 1960). Hormay (1964) has shown that periodic heavy use of bitterbrush results in increased vigor and increased production as compared to non-use. The site on which bitterbrush is growing will influence its production. This is due to soil, precipitation, and associated vegetation (Hormay, 1943; Volland, 1963).

Some investigators have given guide lines for the carrying capacity of bitterbrush on good sites (Hormay, 1963; Committee, 1963; Guenther, 1960; Hubbard, et. al. 1960). In general, 500 to 700 mature bitterbrush plants per acre with a crown cover of about 20 percent will support a 100 lb. deer for two to three months. This kind of a stand would have a value of about $1,072 per acre (Guenther, 1960).

Palatability

Palatability and preference have different meanings: palatability concerns the plant characteristics or conditions which stimulate a selective response by animals; preference is selection by the animal of certain plant species.

Relative preference indicates the proportional choice of an animal among two or more foods. It is relative because the animal is restricted in his choice to a limited number of plants (Heady, 1964).

Many factors influence palatability: protein, sugar, acids, fats, minerals, fiber, and lignin. Increasing lignin and crude fiber decrease palatability while the others increase palatability. All of these have been demonstrated to be important in particular studies; however, nothing is absolute (Heady, 1964). Plice (1952) found that sugar was a key factor in cattle preference for forage. He even found that spraying unpalatable material with sugar would render it highly palatable. Swift (1948) found that deer selectively grazed winter wheat that was higher in calcium, phosphorus, and fats. Hormay (1943a) found that palatability of bitterbrush varies between plants, stages of growth, and degree of use. These are reflected in the protein, mineral, lignin, and fiber content. Unfortunately, palatability is not all this simple. Dietz, et. al. (1962b) found that juniper and big sage are higher than bitterbrush in protein, fat, ash, and minerals; however, bitterbrush is more palatable. Other factors, as yet unknown, also influence palatability.

Heady (1964) noted that animals often prefer parts of the plant with higher nutritive value, such as seeds and leaves. It has not been proven, however, whether this is due to chemical makeup or some other factor such as the physical nature of the stem in comparison to leaves. Increasing seasonal age of a plant generally reduces palatability. This is associated with chemical changes within the plant and the leaf-stem ratio of the plant, as well as succulence or hardness of the foliage. Climate, topography, and soil affect palatability through plant chemical composition, turgidity, and hardness of foliage. The growth form of a plant affects palatability with such things as awns, spines, hairiness, position of leaves, stickiness, and texture.

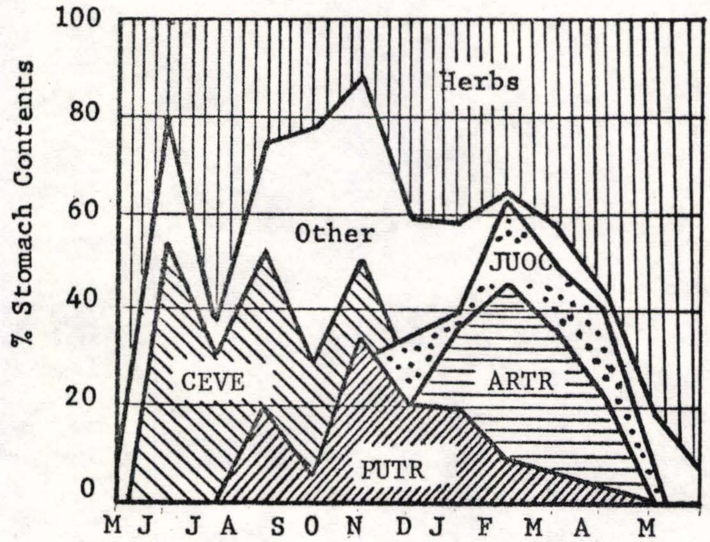
Animal preference is influenced by palatability of the species and by the animal itself: taste is a combined stimulation of salty, sweet, sour, and bitter. Internal animal body processes influence preference through nerve stimulation, blood sugar level, body temperature, movements in the digestive tract, fatigue, etc. Preference is also influenced by conditioning of the animal through previous feeding habits and nutritive and physical environment of the animal. All are interrelated.

Preference for a given species is dependent upon its availability and the availability of other forage choices. For instance, some species are grazed heavily when they occur in small quantities, whereas when they dominate a stand, use is light (Heady, 1964). Bitterbrush is a good example. In pure stands it is lightly used, but where it grows as scattered plants it is often heavily used.

Different animals have different preferences; a fact well known and documented. However, the same animal shows changes in preference between areas, from one season to another, over a period of a few days, and even within the same day. Furthermore, preferences between individuals of the same species may vary. Reduction of the available feed supply by grazing will alter preference of the same animal (Heady, 1964). With this background let us look at the palatability of bitterbrush.

The palatability of bitterbrush in regard to deer is generally thought to be higher than any other browse species in the western states. However, this is not always the case, even during the period of greatest deer preference for bitterbrush. Such species as mountain Mahogany, cliffrose, (Cowania stansburnii), oak, serviceberry, and alfalfa (Medicago species) have been listed as having higher palatability (Julander, 1955; Dietz, et. al 1962a; Smith and Hubbard, 1954; Riordan, 1957). Many other species are more palatable at other seasons of the year: big sage has been well browsed while ample volumes of bitterbrush, mahogany and serviceberry have been available (Dietz and Yeager, 1959). Any discussion of palatability, therefore, must consider season of the year and growing conditions.

Figure 5. Seasonal shift of deer preference based on stomach contents.



Season of use greatly influences palatability of bitterbrush. Figure 5 demonstrates not only the seasonal shift of deer preference for bitterbrush but also shifts in preference for other species. All investigators studying palatability agree that deer do shift their preference to bitterbrush in the fall. Its importance gradually increases in late fall and early winter then diminishes toward mid-winter and spring (Holmgren and Basile, 1959; Hormay, 1953a; Smith, 1953; Leach, 1956; Julander, 1955; Lasson, et. al. 1952). The dates when deer begin using bitterbrush vary considerably between geographic locations, as does season of the year when they make the most use of bitterbrush and the date when they stop using bitterbrush. Table I indicates that cattle and big game not only shift their preference for bitterbrush, but also change preferences for plant communities. Hormay (1943a) and Leach (1956) both found that antelope begin grazing bitterbrush much earlier in the summer than deer; however, it is not such an important component of their total diet. Palatability of bitterbrush also varies between years as indicated in Figure 6 (Leach, 1956). Julander (1955) and Lasson, et. al. (1952), have also demonstrated yearly fluctuations in animal preference for all species of forage. Seasonal and yearly shifts in preference seem to be caused by physiological condition of the species and nature of the plant community (Heady, 1964).

The seasonal shift in preference by livestock is similar to that of deer. During the summer, cattle generally prefer grass instead of bitterbrush (Julander, 1955; Sneva, 1963; Dasman, 1949; Holmgren and Basile, 1959; Hormay, 1964). Both sheep and cattle tend to eat more bitterbrush as fall approaches. This seems related to the physiological changes in grass.

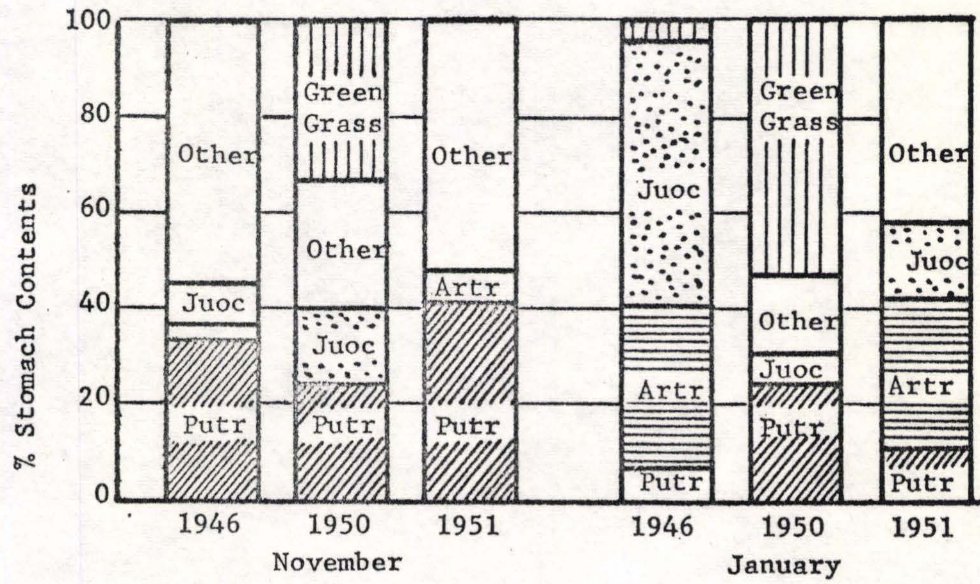


Figure 6. Yearly fluctuations in animal preference based on stomach contents.

TABLE I

Variation of bitterbrush palatability by season and type of vegetation according to percent of animal diet (Julander, 1955).

Summer Range

Vegetation Type	Deer	Cattle
Aspen/browse	47%	3%
Mountain brush	18%	24%

Winter Range

Vegetation Type	Deer	Cattle
Juniper/Sage/Cliffrose	14%	28%
Juniper/Sage/Bitterbrush	33%	69%
Gamble oak/Sage	8%	13%
Pinion/Sage/Bitterbrush	79%	13%

Bitterbrush palatability is influenced by the composition of the vegetation. Palatability tends to be increased when bitterbrush becomes a minor component of the vegetation (Committee, 1951; Hagen, 1953; Lasson, et. al. 1952). In northern California, bitterbrush accounts for half the forage ingested by deer during October, yet it is only two percent crown cover in a stand dominated by big sage (Lasson, et. al. 1952). Dietz and Yeager (1959) found in Colorado that the use on bitterbrush is apparently less when big sage and other shrubs are present. In another study, Dietz, et. al. (1952b) found that a combination of browse species enhanced palatability of bitterbrush for pen-fed deer. Table I indicates palatability of bitterbrush in various plant communities during two seasons of the year. Note that preference differs considerably. The importance of bitterbrush in deer winter diets varies from 8 to 79 percent depending upon the plant community while cattle preference varies from 13 to 69 percent. Note also that plant communities affect deer and cattle preference differently. In many cases, however, bitterbrush does not become as important in the diet of livestock as it does in deer. Such species as serviceberry, snowberry, willow (Salix species), aspen (Populus tremuloides), and others are often preferred (Cook, et. al. 1948; Smith, 1953; Cook, 1953). But where bitterbrush is virtually the sole palatable shrub, both cattle and deer will use it heavily (Sneva, 1963; Dasman, 1949; Edwards, 1942; Cliff, 1939). Soil and other site characteristics also affect bitterbrush palatability (Hormay, 1943a).

Many tables will show bitterbrush as rating at some level in the species preference for deer, elk, and domestic livestock. However, one may not immediately assume major direct competition. Competition exists only in cases where excessive use is made of bitterbrush. Dual use may be expected and should cause no concern when adequate control of animal numbers is available (Riordan, 1957; Julander, 1955).

Condition and Trend

Evaluation of condition and trend by use of vegetation standards is extremely limited. A few areas in Oregon and Washington have standards which designate the amount of bitterbrush necessary for excellent conditions. In Washington bitterbrush should have a 10 percent crown cover in the east side browse type (Everson and Clark, 1946). In the southern Blue Mountains, it should average 15 percent in the pine-bitterbrush-Ross' sedge type and 5 percent in the pine-elk sedge type (R-6 C&T Standards, 1963).

The kind of animal and the combination of animals have different effects on range condition. In some areas a combination of season long cattle use and deer winter use have deteriorated the range (Committee, 1951; Holmgren and Basile, 1959). On the other hand, Mustard (1959) found in Colorado that browse increased in cattle pastures whereas it decreased in sheep and deer pastures. Gysel (1960) studied the effect of deer and elk grazing in a wildlife area in Colorado. The most highly palatable browse species were completely eliminated outside of exclosures. The authors felt this was due primarily to deer browsing. In this case, areas outside the exclosures were in excellent condition grass and poor condition browse.

Trend in range condition may be difficult to evaluate. One must discover the factors causing range deterioration before he can prescribe corrective action. Julander and Robinette (1950) found that determining causes for range trend is extremely difficult where deer and cattle graze an area at the same time. Animal use may not be the only factor causing a downward trend in bitterbrush. In northern California, elimination of livestock permitted an increase in perennial bunchgrass which has prevented bitterbrush reproduction and is causing a downward trend in this species (Committee, 1963). Increasing tree cover may also decrease bitterbrush (Hormay, 1943a; Volland, 1963).

Indicators of trend are excessive browsing of bitterbrush and other palatable browse, age class distribution of bitterbrush in which lack of reproduction indicates downward trend, and low vigor due to browsing or plant competition (Lasson, et. al. 1952; Committee, 1963; Holmgren and Basile, 1959).

Change in trend can be accomplished through animal management if animals are the cause of range deterioration. Where livestock and game compete for bitterbrush, the simplest method is to shorten the season of use in the fall when livestock begin using bitterbrush (Julander and Robinette, 1950; Dasman, 1949).

However, this will only be effective if deer numbers are controlled at the same time. Too often reduction in livestock use has been accompanied by an increase in game use which resulted in continued deterioration of bitterbrush. Where herbaceous vegetation competes severely with bitterbrush, spring use by livestock may be used to somewhat weaken the perennial grasses and reduce their competition (Committee, 1963).

Competition Between Livestock and Game

Several questions must be answered when dealing with livestock--big game relationships (Committee, 1950). These are:

1. What is the nature and extent of competition for forage between big game and livestock?

2. To what degree can important game forage species be utilized?

3. What are the indicators of condition and trend that can be used for guides in management?

4. How can grazing capacity of range be determined for combined use of game and livestock?

5. What are the seasonal and permanent migration routes of big game?

In addition, the following points must be considered. Most of them can be easily determined for livestock.

1. How can big game numbers be determined with reasonable accuracy?

2. What annual production for hunter harvest can be expected from game herds?

3. What are the effects of big game on watershed values?

4. What are the factors affecting big game productivity and how may they be controlled?

5. What are the social and economic values involved?

No single study or combination of studies has fully evaluated these questions. Maximum sustained grazing is limited by the need for proper use of perennial grasses used exclusively by cattle and the proper use of shrubs and forbs used exclusively by deer as well as the proper use of shrubs and forbs palatable to both kinds of animals (Julander, 1955).

Evaluation of competition deals with two factors: the extent to which game and livestock use the same areas, and the extent to which they prefer the same species.

The amount of competition between deer and livestock for a particular area is influenced by the topography and the vegetation (Julander, 1955; Yeager, 1960). Deer distribution is determined primarily by suitable forage, whereas cattle distribution is influenced mainly by steepness of slope, availability of water, and availability of forage. In general, deer prefer areas with a combination of grass, forbs, and browse. Cattle prefer predominately grass areas. Real competition between deer and livestock is limited to those areas where both classes of animals graze either during the same season or at different seasons. Many times these are confined to deer winter ranges (Julander and Robinette, 1950).

Cattle and deer compete directly for bitterbrush in the fall of the year (Julander, 1955; Committee, 1951, Edwards, 1942; Holmgren and Basile, 1959; Dasman, 1949). However, this competition seems to be influenced by the kind of plant community in which bitterbrush is growing. In some instances, cattle do not compete seriously with deer (Yeager, 1960; Mustard 1959; Gaufin, et. al. 1950).

Reports of sheep and deer competition have also varied. In some cases these animals compete directly for bitterbrush (Edwards, 1942; Yeager, 1960; Mustard, 1959; Gaufin, et. al. 1950). In other instances, competition is minor. Again, season of use is important; greatest competition occurs in the fall.

Most investigators have reported that cattle, sheep, and deer obtain the bulk of their forage from different species. Real competition becomes apparent only after excessive utilization (Riordan, 1957).

Game Management and Use

Deer require a variety of browse, grass and forbs for optimum growth and development. Animals have been found dead from starvation with their rumens full of big sage and grass. (Dietz, et. al. 1962a; Lasson, et. al. 1952; Dietz and Yeager, 1959). A mixture of browse, in addition to bitterbrush, is desirable for excellent deer winter range.

As noted previously, deer shift their preference to bitterbrush in the fall and then shift away from it during the winter. This apparently is related to available nutrients which are gradually reduced as the winter progresses. Big sage maintains its high nutritive value which may account for increased late winter use on this species (Dietz et. al. 1962b). Fertilization has been shown to increase the palatability of bitterbrush on the Deschutes National Forest (Committee, 1963).

Development and growth of deer are related to the amount of available bitterbrush. During years of low bitterbrush production, deer herds often suffer severe losses (Robinette, et. al. 1952; Cliff, 1939; Julander and Robinette, 1950). Schneider (1963), working in Oregon, found that the number of fawns per 100 does is related to bitterbrush production. Fawn production lags about one year behind abundant bitterbrush forage.

All investigators recognize that either-sex hunting is necessary to control deer numbers. They have also noted that reduction in livestock numbers will solve nothing unless game animal use can be controlled (Julander and Robinette, 1950; Edwards, 1942; Dasman, 1949; Aldous, 1945; Committee, 1951; Holmgren and Basile, 1959). In some cases, however, either-sex hunting has not been entirely successful in balancing deer herds with the range productivity. (McConnell and Dalke, 1960; Julander and Robinette, 1950). Apparently this was due to limited season and low hunter pressure. Cliff (1939) noted that bull elk hunting resulted in increased elk herds which reduced deer herds because of competition for winter forage. He suggested favoring deer over elk since three deer may be wintered for one elk. These three deer would offer more hunting than would the single elk.

Deer generally migrate from bitterbrush winter ranges to higher elevation summer ranges in the mountainous west. The reasons for this migration are various. Apparently deer start their spring migration in response to plant nutritive quality (Dietz, et. al. 1962b; Yeager, 1960; Holmgren and Basile, 1959; McConnell and Dalke, 1960). Fall migration is caused primarily by cold weather and snow. Weather seems to be the primary factor determining the length of time deer spend on winter ranges (Schneider, 1963; Committee, 1951; Holmgren and Basile, 1959). Their arrival on the winter range is determined by the descending snow line in the mountains and their departure in the spring is determined by spring growing conditions of temperature and precipitation which influence spring growth of forbs and grasses.

Deer distribution on winter range is influenced by topography, microclimate and vegetation. Yeager (1960) feels that a long, south facing valley slope is ideal when it has occasional rock outcrops, wooded north or east facing sub-slopes, deep soil spots, broken micro-relief, and good distribution of water. Flood plains and level terrain are hazardous due to the possibilities of occasional deep snow accumulation. In general, deer prefer to winter on snow free areas (Yeager, 1960; Holmgren and Basile, 1959). South slopes have more direct insolation, are usually warmer, and are usually snow free. Vegetation influences winter deer distribution. Those areas with bitterbrush plus other browse species receive heavier use than grassland areas or pure big sage (Julander and Robinette, 1950; Julander 1955). Deer may develop an instinct or habit of returning to favorite winter range areas. This results in uneven distribution of animals.

Vegetation seems to be the major factor influencing deer distribution on spring, summer and fall range. When snow is not a problem, topography has little influence on deer distribution (Julander and Robinette, 1950; Reynolds, 1962).

Livestock Management and Use

The distribution of livestock is influenced by topography, water distribution, and vegetation (Julander, 1950; Reynolds, 1962). Steepness of slope definitely limits cattle movement. They prefer vegetation that is dominated by grass but will graze other areas, prefering as much grass as possible. In forest range, cattle tend to prefer open areas where grass is more plentiful and has a higher sugar content. Sheep distribution is often guided by herders and is limited mainly by denseness of vegetation.

Both sheep and cattle shift their preference to bitterbrush in the fall of the year. However, this shift is determined by the kind and growth stage of more palatable vegetation (Edwards, 1942; Julander, 1955; Cook, et. al. 1948; Hormay, 1964). Cattle use of bitterbrush is determined by the nutrient status of the available grass, the amount of grass available for use, and fall rains which cause a green-up of the grass. Sheep preference is tempered by the amount of leaves available in the fall of the year. In many cases, bitterbrush becomes the most palatable plant in the fall. This is particularly true when it is a minor component of the vegetation (Hormay, 1943).

Grazing systems designed for cattle are intended primarily to increase grass production (Driscoll, 1956; Hormay, 1964). To accomplish this, spring use is generally limited and fall use is encouraged since grasses are damaged least under these conditions. However, this encourages cattle use at the time when their preference shifts to bitterbrush. The best known systems are deferred rotation and rest rotation. See Appendix IV for details.

These systems of management can have both desirable and adverse effects on bitterbrush. Sanderson, et. al (1963), found that the strong competition between perennial bunchgrass and bitterbrush could be reduced by killing the bunchgrasses. Heavy spring grazing by livestock can be used to weaken the grasses and reduce the competition (Hubbard and Woolfolk, 1961). On the other hand, shortening of the grazing season on National Forest land to reduce livestock use of bitterbrush will result in earlier fall grazing by these animals on Bureau of Land Management and private range which are generally the key winter deer ranges (Dasmon, 1949; Committee 1951). This results in increased use on these key winter deer ranges (Edwards, 1942; Committee, 1950). Mueggler (1950) demonstrated the results of spring versus fall sheep grazing in Idaho. Fall use did not materially affect the vegetation. Spring grazing resulted in a 28 percent reduction of grass and forbs and a 175 percent increase in brush. Bitterbrush increased 90 percent under spring use.

Costello and Price (1939), working in Colorado, found that flowering and drying of grass and forbs is dependent upon precipitation and temperature. This flowering and drying can be predicted by the date of snow melt. As herbs dry, sheep and cattle shift their preference to browse. Predicting this shift of preference might be of value.

Hormay (1964) has suggested employing sufficient cattle use to change the form of bitterbrush into a smooth, cushion shape. In this way, many leaves and some annual twig growth are protected by thick stems. He has also found that bitterbrush maintains its vigor in this form and will produce abundant leaders which will be available to deer during years of rest.

As a general principle, Dasmon (1949) has proposed that livestock be permitted to crop 50 percent of the usable bitterbrush production leaving 50 percent for game animals.

Forest Management

Logging influences forage production for wildlife. Unfortunately, little work has been done in areas with an understory of bitterbrush. Therefore, results from other kinds of vegetation will be reviewed.

Pengelly (1963) and Reynolds (1962b) found that logging increased herbs and some shrubs in areas where subordinate vegetation reproduced largely by rhizomes. Maximum increase in production occurred 10 to 15 years after logging. Porter (1959) found that timber cutting did not benefit game animals in the lodgepole-spruce (Picea engelmanni) fir (Abies lasiocarpa) type in Colorado due to excessive logging slash which prevented deer from using the forage. Garrison (1960), working in Oregon, and Washington, found that logging increased herbaceous vegetation; but after seven years, shrubs were still 11 percent below their pre-logging importance. In this case, the area was deer summer range and contained little bitterbrush. The increase in forbs, however, probably increased deer forage production.

Volland (1963), working in the pine-bitterbrush of southeastern Oregon, observed that logging severely damages and kills bitterbrush. Logging in areas where ceanothus and manzanita grow in conjunction with bitterbrush will usually eliminate bitterbrush permanently. The ceanothus and manzanita sprout after logging and completely dominate the site. Hormay (1943a) has found that bitterbrush is apparently intolerant of shade and grows best in openings in the forest canopy. It is conceivable that logging and thinning could result in greater browse production if plant damage were limited.

Reynolds (1962a), working in Arizona, found that logging influences the distribution of livestock, deer, and elk under the unit area control harvest system. The animals tend to graze in the small openings created in the forest. He has suggested the following modifications in timber harvesting to benefit livestock and deer:

1. Shift areas of logging to benefit deer population.

2. Shorten the timber cutting cycle to keep forage production high.

3. Thin pole size stands to increase herbaceous understory.

4. Reduce density of timber on north slopes

Some work has been done in Oregon and Idaho testing the feasibility of spraying shrubs with 2,4-D and 2,4,5-T to reduce competition with trees (Gratkowski, 1961a and 1961b; Dahms, 1955; Newton, 1963; Curtis, 1961). They found that Ponderosa pine is more sensitive to spray than Douglas-fir. This sensitivity decreases as fall approaches. In addition, they found that each shrub is susceptible to spray at different times of the year and that sprouting species are most difficult to kill. Much of the work was concerned with manzanita and ceanothus. Apparently no one has attempted to selectively spray these shrubs where they are growing in competition with bitterbrush. If this were possible, it would not only increase tree growth but also the forage production of bitterbrush.

Fire has been found to be useful in killing shrubs and reducing competition with trees (Weaver, 1957; Van Sickle, 1959). When fire is used, however, it will also kill bitterbrush.

Revegetation

Seed Collection and Handling

The only source of bitterbrush seed is native stands. Production varies according to the site, season, and diversity of soil and climate within an area. Excellent seed crops are produced every second or third year. Where precipitation is 10 inches or more, or when plant roots reach underground water tables, more frequent and higher production occurs. The variation in seed production is related to precipitation. It generally lags one year behind a season of good growing conditions during which leaders grow three inches or longer. This permits forecasting good seed production one year in advance (Nord, 1962).

Seed ripening occurs over a very short period of time; from five to seven days. The date of seed ripening varies between years, elevations, and between geographic locations (Hormay, 1943a; Holmgren and Basile, 1959; Committee, 1963; Nord, 1962). Since the seed falls to the ground shortly after ripening, the period of collection is short. Seeds should be collected when they are plump and grayish in color and when the red juice in the seed coat is well solidified (Hormay, 1943a; Holmgren and Basile, 1959). Seed should be collected from plants in the same area and site on which it is to be planted. This is due to the many genetic strains of bitterbrush which strongly influence its ability to survive and compete (Nord, 1962).

Hand methods of collecting have been widely used. This consists of placing a cloth or screen below the bush and gently rapping to knock off the ripe seed. Seeds which are not ripe or those which are not viable will remain on the bush. One man can often collect one pound of seed per hour in this manner (Nord, 1962; Holmgren and Basile, 1959). A mechanical seed harvester is being developed which consists of two long hoses connected to a vacuum pump placed in the back of a four-wheel drive vehicle. A three-man crew can collect up to 160 pounds of seed a day with this machine (Nord, 1962).

Collected seed may be stored for three to four years in dry, 41° F conditions without losing significant viability (Hormay, 1943; Brown, 1959). Seed coats should be removed prior to stratification or storage since they tend to reduce germination of the seeds (Hormay, 1943a; Holmgren and Basile, 1959). The seed coats can be removed by rubbing with a rubber faced paddle or running seeds through a coniferous tree seed dewinger.

Treatment to break dormancy can be accomplished in several ways. Seeds may be stratified in a medium of moist sand at 36° F to 40° F for four to five weeks. However, this has two disadvantages: the seeds must not be allowed to dry out prior to planting, and the seeds are soft which prohibits treatment to prevent rodent deprivation (Holmgren and Basile, 1959; Brown, 1959). Stratification is, of course, not necessary where seeds are planted in the fall.

A number of chemical methods have been tested for their ability to break dormancy (McConnell, 1960; Peterson, L. 1953). Thiourea treatment was found to be best. Most investigators recommend a 3 percent solution of thiourea and a four to six minute soak of bitterbrush seed (Hubbard et. al. 1959; Holmgren and Basile,1959; Pearson, 1957). The optimum time of soaking ranged from three to eight minutes, apparently depending upon the strain of seed used. Hubbard (1958), working in northern California, found that field germination varied between areas where seed was planted. Thiourea treatment resulted in better germination under nine inches of precipitation than did stratification. Stratification was superior in a 12 to 14 inch precipitation zone.

Rodents and birds may be discouraged from consuming bitterbrush seed by treating with an endrin and aluminum powder mixture (See Appendix V for details). In mixing the rodenticide with the seed, do not agitate more than 3 to 4 minutes. The treated seed is poisonous and should be handled with gum dipped gloves.

This treatment should be done just a few days prior to planting. Stratified seed cannot be used due to its soft seed coat (Holmgren and Basile, 1959; Brown, 1959).

Bitterbrush cuttings may be rooted by treatment with a rooting hormone (Nord, 1959d; Hubbard, et. al. 1959). One year after rooting some of the plants began to flower. This could be a valuable means of propagating desirable strains of bitterbrush. It is not economical for field planting (See Appendix VI).

Bitterbrush may be grown for transplanting similarly to trees, however, field results have been disappointing (Riordan, 1958; Brown, 1959).

Planting

In general, planting should be considered only as an emergency measure to be applied on areas in critical condition (Holmgren and Basile, 1959). The first question one must answer is why the bitterbrush is in such a degenerate condition that revegetation is necessary (Hubbard and Woolfolk, 1961). A seeding cannot be successful unless the factors causing deterioration of bitterbrush have been determined and eliminated.

The two principle factors most often causing deterioration are overuse by livestock and overuse by game. Prior to planting, control and management of animal numbers must be assured (Hubbard, 1962; Basile and Ferguson, 1960; Committee, 1963). Control of livestock generally offers few problems. Control of deer numbers is complicated by lack of man's control over deer movements and season. These are largely climatically controlled and instinct influenced (Hubbard and Woolfolk, 1961). Deer numbers must be brought under control before planting is started, and must remain under control after the plants are established (Committee, 1963). Most effective control of game animals is through either-sex hunting on the particular winter range in question. Hunting should be conducted in the fall after game are in the area (Holmgren and Basile, 1959).

Several factors should be considered when sites for planting bitterbrush are selected (Hubbard, 1962; Holmgren and Basile, 1959; Plummer, 1958; Plummer and Jenson, 1956; Committee, 1963; Hormay, 1943; Brown, 1959).

1. Areas that are growing or have grown bitterbrush: If age classes of bitterbrush are one to two years apart, chances of seedling establishment are good, if they are five or more years apart chances are reduced.

2. More moist sites should be favored over dry sites: Where bitterbrush has been eliminated, vigorous growth of big sage may indicate a good potential site.

3. Plant communities may be used to indicate site potential: In Utah the mountain brush zone is best and the juniper type intermediate for bitterbrush planting success.

4. Soils alone may be an indicator of site potential: Best sites are on deep, coarse textured, well drained soils with a pH between 6.0 and 7.0 to a depth of five feet.

5. Snow free areas on the deer winter range should be considered as high priority.

6. Burned bitterbrush range offers excellent opportunities for planting. It should be seeded during the year of the fire and only in those spots that were burned hot. Pure cheatgrass range is a poor risk because fire was not hot enough to reduce competition.

7. Abandoned farm land may be seeded but often produces a poorer stand than unfarmed areas.

8. Where possible, planting sites should be selected in the less critical winter ranges. This will remove pressure in the key areas which may then be seeded following an open winter.

Fall planting has been generally found superior to spring planting in Washington, Idaho, and northern California in low precipitation areas (Holmgren and Basile, 1959; Hubbard and Sanderson, 1961; Brown, 1959). Spring planting on moist sites has resulted in higher survival in northern California (Hubbard et. al. 1959; Committee, 1963).

Fall planting has the advantages of an extended season for planting, minimum soil moisture problems, and automatic seed stratification. Its disadvantages are increased time for rodent deprivation of seed, and frost heaving. Spring seeding has the advantages of minimum time of seed exposure to rodents and often higher seedling survival. It has the disadvantages of a limited planting season and the necessity of seed treatment.

Plant competition must be controlled for successful planting (Holmgren, 1954; Brown, 1959; Hubbard, et. al. 1959). Methods of eliminating competition depend upon conditions present: burns with numerous hot spots can be hand planted without further treatment. Dense cheatgrass areas may require two years' cultivation with disc plows. In many cases, simply scalping a two- to three-foot square area around planting sites may be sufficient.

Lack of available soil moisture is the most important single cause of seedling mortality (Brown, 1959; Hubbard, 1956). Available moisture is determined by soil texture which influences moisture retention of spring precipitation during germination and emergence of seedlings.

Depth of seed planting is determined by soil moisture holding characteristics and spring precipitation. Most recommendations suggest one-half to three-quarter inch deep in finer textured soils with good moisture retaining qualities and about one and one-half inches deep in coarser textured soils (Holmgren and Basile, 1959; Hubbard, 1956; Brown, 1959; Committee, 1963). A seeding depth of one-half to three-quarters inch is often recommended for drilling (Basile, 1957; Holmgren and Basile, 1959). Seedling emergence decreases with increasing depth of planting (Basile, 1957).

Hand planting has generally been the scalp and spot seed method (Basile and Ferguson, 1960; Basile, 1957; Hormay, 1943). A two- to three-square foot area is scalped of all vegetation. Then six to eight seeds are placed in each of three seed spots in the center of the scalped area. These seed spots are about three inches apart and the seed planted at a depth suitable for the soil and precipitation characteristics. Scalped areas should be four to seven feet apart in all directions. This spacing should result in 1,000 to 2,000 established bitterbrush per acre.

Drilling may be accomplished with either the rangeland drill or a standard grain drill (Nord, 1958; Committee, 1963, Hubbard, et. al. 1959; Holmgren and Basile, 1959). Bitterbrush seed must be mixed with rice hulls at about a 1 to 3 ratio for satisfactory drilling. (See Appendix VII for details). Recommendations vary considerably for the amount of seed to drill. In northern California, Nord (1958) recommends 6-1/2 to 7 pounds, whereas Holmgren and Basile (1959) recommend 1-1/2 to 2 pounds for southern Idaho.

On abandoned farm land or completely degenerate native range, seeding of grass and even trees with bitterbrush has been recommended. Bitterbrush should be drilled in rows five feet apart or every third drill row with the rangeland drill (Holmgren and Basile, 1959; Committee, 1963). Use six to eight pounds of grass seed and three to four pounds of pine if it is a degenerate timber site. In fall planting, grass seed should not be planted before October.

Brown (1959) has reported one of the few successful uses of transplanted bitterbrush. Transplanting requires good nursery stock with the proper balance between roots and tops; 12 to 18 inch sizes are best. Transplants must be handled with extreme care to be sure roots are not allowed to dry out at any time.

A satisfactory stand will contain 500 to 2,200 established plants per acre (Committee, 1963). Cost for drilling or handseeding runs around $20 to $22 an acre, while transplanting costs up to $75 per acre (Committee, 1963; Brown, 1959).

Rodent control may sometimes be necessary after establishment of a planting (Plummer, 1958). Rabbit control measures depend upon the season: during the winter, poisoned alfalfa hay is effective; in the spring, poisoned grain; and during late spring and summer, poisoned salt is most effective. Other rodents have been controlled with grain poisoned with strychnine or 1080 placed at regular intervals, preferably in quart cans which tend to prevent access of birds and larger animals. All poisons must be placed in such a manner that they will not kill desirable animals. While 1080 has been recommended, its use should be discouraged because of its chain reaction effect: rabbits killed by 1080 can kill vultures and other carrion eaters through the 1080 contained in the bodies of the dead rabbits.

Use of Spray and Fire

Hyder and Sneva (1962) tested the feasibility of controlling big sage to release bitterbrush. They found that 2,4-D is slightly more selective for sage and can be applied at the rate of 1-1/2 to 2 pounds acid equivalent per acre. Bitterbrush was damaged least when sprayed prior to first leaf appearance, while the greatest damage occurred from first leaf occurrence to early fruit development. Spraying at any time killed virtually all leaf tissue and current twig growth of bitterbrush; however, spraying at the time of leaf origin and before the appearance of twig growth resulted in only a small amount of dead tissue. At this time, sufficient growing conditions generally remained so that bitterbrush could again produce leaves and twig growth. In the autumn, only slight evidence of spray injury remained. All bitterbrush plants smaller than 12 inches were consistently killed under all conditions. Mortality of big sage ranged from 80 to 90 percent. Since sage is a desirable component of deer browse, a 100% kill should not be attempted. Bitterbrush production is increased when selectively sprayed to control sagebrush. (Blaisdell and Mueggler, 1956a).

Fires have been used with variable results, most of them unsatisfactory for bitterbrush. In Idaho, bitterbrush plants often sprout after burning or clipping (Blaisdell and Mueggler, 1956b). Early summer and late spring burning resulted in more sprouting. Sprouting depends on heat of the fire which may damage bud masses or meristematic tissue at the soil surface. Results in Idaho have been variable (Mueggler and Blaisdell, 1958; Blaisdell, 1953 and 1950). In some cases, bitterbrush is severely injured by burning. In other cases it almost regained its pre-fire dominance after seventeen years. On the other hand, Hubbard and Woolfolk (1961) have found that fire will eliminate bitterbrush in northern California.

Fire in forest areas that contain bitterbrush has been shown to be invariably detrimental (Weaver, 1957; Countryman and Cornelius, 1957).

Summary

Satisfactory management of bitterbrush requires a sound knowledge of its growth form, seasonal development, reproductive characteristics and palatability. All these characteristics are modified by the plant community in which it grows and the soils and climate in which it exists.

One word of caution--the material reviewed in this paper pertains to specific areas encompassing a limited number of plant communities, soils, and climates. Few areas have been comprehensively studied. Therefore, one should expect to find variations and differences from the material presented here. The main value in reviewing past work is to become familiar with the diversity of results and conclusions. This will often provide ideas for investigation of existing problems.

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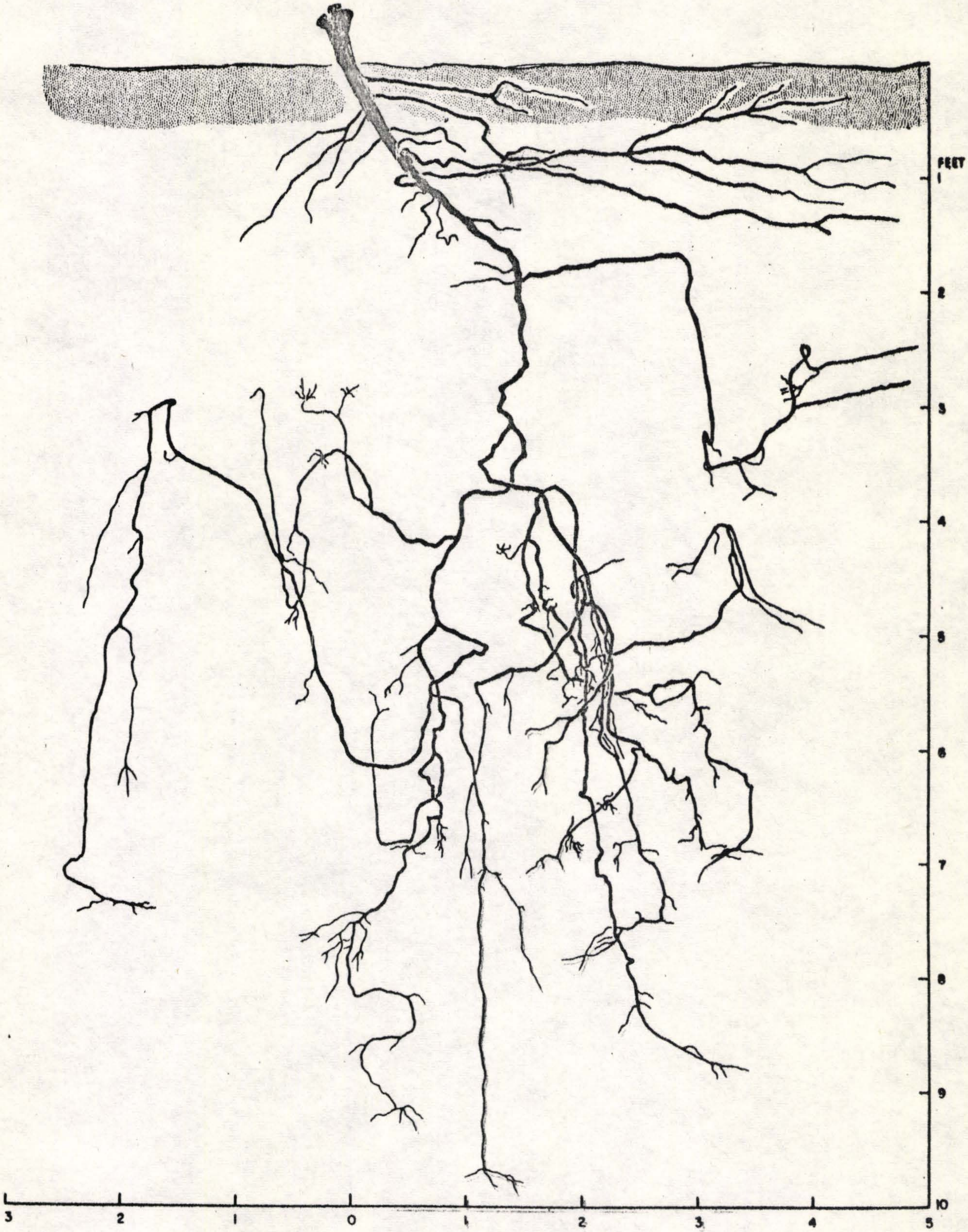
APPENDIX I

Root system of an antelope bitterbrush plant between 25 and 30 years old with strong upward curvatures of roots. (McConnell, 1961)



APPENDIX II

Method of Determing Utilization of Bitterbrush (Hormay, 1943 b)

1. Sample plots should be narrow and long enough to include 20 to 25 averaged sized plants: about 20 inches wide and 120 to 200 feet long.

2. Establish 20 to 25 plots in important range areas. Distribute them through the stand.

3. Mark each plant with a steel stake and label.

4. Measure the average diameter of each plant's crown to the nearest inch; measure in two directions and average the measurements, record per plant.

5. Estimate the average length of all ungrazed twigs in inches, record per plant.

6. Estimate the percentage of the total amount of twig growth grazed on each plant, record. Steps 4, 5, and 6 should be done at the same time for each bush. The presence of leaves may tend to affect these estimates.

7. Amount of forage is expressed as an index obtained by multiplying the average leader length times the area of the crown (ungrazed leader length X crown diameter = forage index). Total these for each plot, average the plots for an average of the type.

8. Forage used is obtained by multiplying the amount of forage index times the percentage use of twig growth for each plant (forage index x % use = forage used). Average for the plot. This expresses the total foraged used.

9. Percent of use is obtained by dividing the forage used by the total forage produced and multiply by 100 (forage used divided by amount of forage x 100 = % use).

10. Average the percent use of the plots for the average percent use of the type. Reliability depends on the number of plots used and the accuracy of twig length and utilization estimates.

APPENDIX III

Twig Length Method of Determining Browse Use (Smith and Urness, 1962)

*1. Label one branch per bush with a numbered tag. See below for the required number of branches.

2. Measure all current twigs longer than one-half inch above the tag. Measure to the nearest centimeter to eliminate fractions of inches. Record each measurement.

3. Take measurements in the fall after livestock leave and prior to deer use. Retake measurements in the spring after deer leave the area.

4. Determine percent use by dividing the spring length of twigs by the fall length of twigs and multiply by 100 (spring length divided by fall length x 100 = % use). Do this for each tagged branch, average for the type.

*This study found that the following number of tagged branches are required:

At less than 30% use, requires more than 350 tagged branches.
At 30 to 50% use, requires 100 to 250 branches.
At 50 to 80% use, requires 35 to 45 branches.

These are the number of branches required for a 20% allowable error at the 95% level: means that the actual utilization is plus or minus 20% of the use determined by sampling, and that this is true 95 times out of 100.

NOTE: Observer error was highest on big sagebrush and lowest on bitterbrush. Found some trouble in determining current year's growth on mountain mahogany, and to some extent on bitterbrush. Must be very careful in recording all twigs. Even under very light use, only 23% of the branches measured in the fall had the same number of twigs in the spring.

APPENDIX IV

Deferred Rotation System of Grazing (Driscoll, 1956).

Allotment is divided into two pastures with approximately equal carrying capacity. Grazing is deferred on one until the grasses have passed the flowering stage. This is often half the season. During this time, all the livestock are in the other pasture. About mid-season, the animals are transferred to the spring deferred pasture and allowed to graze there the rest of the season.

Rest Rotation System of Grazing (Hormay, 1964).

The allotment is divided into the number of pastures required to improve the range. The requirements are based on plant physiology and reproductive habits.

Plants are grazed rather hard the first year, then allowed to rest one year to improve vigor for seed production. The year of seed production (third year), the pasture is grazed heavily after seed has ripened in order to trample it into the ground and to afford fall grazing. The area is again rested for one to three years to afford seedlings time to become established. The number of pastures is determined by the number of years required to complete one cycle, i.e. if two years are required for seedling establishment, five pastures are required--first year spring grazing, second year rest for vigor, third year seed production and fall grazing, fourth year rest for seedling establishment, fifth year rest for seedling establishment.

About 60 to 70% use is made of all forage during the years of grazing which means nearly 100% use of the most palatable species including bitterbrush. This occurs on only one pasture in five. It tends to make bitterbrush into a smooth, compact form of growth which will withstand heavy use and still retain high vigor.

APPENDIX V

Treatment to Prevent Rodent and Bird Damage to Bitterbrush Seed (Holmgren and Basile, 1959).

Mixture is composed of four parts: water, adhesive rodenticide and aluminum powder.

1. Dilute one (1) part of Dalletex No. 512R in nine parts of water to make one gallon.

2. Dissolve one (1) pound of 50% wetable endren in the gallon of water.

3. Dissolve 2.6 pounds of wetable powder of Arisan-75 in the gallon of water.

This mixture is poisonous and must be handled with caution. Use the above gallon mixture for 100 pounds of seed.

Mix the seed at the rate of 25 pounds per batch in a conventional cement mixer. While mixing, add enough aluminum powder to coat the seed. Do not mix more than three to four minutes.

Treat the seed a few days prior to planting. The seed is poisonous and must be handled with gum dipped gloves.

Stratified seed cannot be used due to the soft seed coat which will deteriorate on mixing with the liquid.

Allow the seed to dry out after mixing.

APPENDIX VI

Treatment for Rooting Bitterbrush Stem Cuttings (Nord, 1959 b).

Cut stems shortly below last year's wood. Cuttings should be taken in the spring of the year and should be about six (6) inches long.

Moisten in water and dip in Indol-3-butyric (IBA) acid in talc. A 0.1% concentration gives best rooting results.

Found that there was 66% rooting: roots grew to three inches after 30 days in a moist sand--vermiculite mixture with a pH of 7.0. After 58 days, the plants were transplanted and all rooted stems produced leaves and a few flowered. Plants grew up to eight inches in height and roots spread well within three months.

APPENDIX VII

Method of Preparing Bitterbrush Seed for Drilling (Nord, 1958).

Pure bitterbrush seed cannot be drilled satisfactorily. It must be diluted with rice hulls.

Dilute seed at the rate of three parts seed to eight parts hulls (about a 1 to 3 mixture).

Calibration of the grain drill for 6½ to 7 pounds of seed:

1. Drill type: John Deere Van Brunt Model FE 177A, an 18 by 7 grain drill.
2. Fill the hopper 2/3 full.
3. Disengage the seed agitators (the agitators will cause bitterbrush seed to become separated from the rice hulls).
4. Set the feed regulator at 21 notches (equivalent to 88 pounds of barley).
5. Adjust the feed gauge to position No. 2.
6. Make sure the seed and rice hulls are well mixed prior to drilling.

GLOSSARY OF PLANT NAMES

Common Name	
alfalfa	Medicago species
aspen	Populus tremuloides
balsamroot	Balsamorhiza sagittata
big sage	Artemisia tridentata (ARTR)
bitterbrush	Purshia tridentata (PUTR)
bluebunch wheatgrass	Agropyron spicatum
ceanothus	Ceanothus velutinus (CEVA)
cheatgrass	Bromus tectorum
cherry	Prunus species
cliffrose	Cowania stansburnii
crested wheatgrass	Agropyron desertorum
currant	Ribes species
Douglas fir	Pseudotsuga menziesii
elk sedge	Carex geyeri
fescue	Festuca idahoensis
fir	Abies lasiocarpa
juniper	Juniperus occidentalis (JUOC)
Kentucky bluegrass	Poa praetensis
lodgepole pine	Pinus contorta latifolia
manzanita	Arctostaphylos patula
mountain mahogany	Cercocarpus ledifolius
ninebark	Physocarpus malvaceus
oak	Quercus species
ponderosa pine	Pinus ponderosa
Ross' sedge	Carex rossii
serviceberry	Amelanchier alnifolia
snowberry	Symphoricarpus alba
soft chess	Bromus mollis
spruce	Picea engelmanni
squirreltail	Sitanion hystrix
stipa	Stipa species
willow	Salix species